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Key Areas in Waste Management: A South African Perspective

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1. Introduction

"In the era of industrialization, mining and heavy industry became a major factor in the national economy" (Schreck, 1998). Since industry has become an essential part of modern society, waste production is an inevitable outcome of the developmental activities. In the past industry was geared solely towards economic aspects and totally neglected ecological issues. These industries release huge quantities of wastes into the environment in the form of solid, liquid and gases. A substantial amount of these wastes is potentially hazardous to the environment and are extremely dangerous to the living organisms including human beings.

South Africa's re-integration into the global economy and the Southern African political arena necessitates an improved pollution and waste management system. The country's economic and industrial policy has also turned towards export promotion as a pillar of South Africa's development. Therefore, the country has a growing obligation to meet international commitments and to be a globally responsible country. The government therefore promotes an integrated approach to pollution and waste management as a key factor in achieving sustainable development.

The integrated pollution and waste management policy is driven by a vision of environmentally sustainable economic development. This vision promotes a clean, healthy environment, and a strong, stable economy. By preventing, minimizing, controlling and mitigating pollution and waste, the environment is protected from degradation by enhancing sustainable development.

Having outlined all these, there is still a concern with both the detrimental health effects and environmental impacts of sub-optimal management of waste and increasing levels of pollution in South Africa.

The constitution of South Africa (Act 108 of 1996) established the Bill of Rights that ensures that everyone has the right to an environment that is not harmful to their health and well being. Legislative and other measures should be used to ensure that the environment is conserved and protected for future generations.

According to (Karani & Jewasikiewitz, 2007), in the past, the waste management sector was dominated by private sector with selective operations in what makes business sense through recycling of saleable products. Materials mostly recycled included paper and hard board, plastics, glass, tinplate and aluminum. The rest of the waste materials estimated at 10.2 million tons of both general and hazardous end up in landfills.

South Africa's Emissions per capita in 1999 were estimated at 7.8 metric tons of carbon dioxide (CO_2) equivalent and volumes of waste generated in 1992 and 1997 both general and hazardous accumulated to about 500 million tons (Department of Water Affairs [DWA], 1998).
Given this state of development the country has diverse waste stream, the management of which varies in approach, efficiency and complexity depending on the responsibility of local authority. Waste generation rates for the different market segments are shown in Table 1. The table shows that mining was the largest contributor of waste to this increase followed by industrial, power, land use, domestic and trade and sewage. In 1997, the trend in the table shows that mining was still leading in waste generation while a decline was realized in industrial, domestic and trade and sewage. This trend could be as a result of international standards that impact directly on waste generation.

Waste stream	**1992 (CSIR study)**	**1997**
Mining	378	468.2
Industrial	23	16.3
Power generation	20	20.6
Agriculture and Forestry	20	20
Domestic and trade	15	8.2
Sewage sludge	12	0.3
Total	**468**	**533.6**

[a]The table provides information extracted from a study on waste generation rates in millions tons per year in South Africa. The study was conducted by the Council for Scientific and industrial research.

Table 1. Waste generation rates in South Africa in 1992 and 1997[a]

There are ample evidence that improper disposal of these wastes may cause contamination of air (via volatilization and fugitive dust emissions); surface water (from surface runoff or overland flow and groundwater seepage); ground water (through leaching/infiltration); soils (due to erosion, including fugitive dust generation/deposition and tracking); sediments (from surface runoff/overland flow seepage and leaching) and biota (due to biological uptake and bioaccumulation). According to (Misra & Pandey, 2005), contamination of ground water by landfill leachate posing a risk to downstream surface waters and wells is considered to constitute the major environmental concern associated with the landfilling of the waste. In order to safeguard our environment, it is important to regulate such hazardous waste in environmentally feasible and sound manner.
According to the (Department of Water Affairs [DWA], 1998), waste disposal in South Africa is mostly in landfills, but it is estimated that only 10% of landfills are managed in accordance with the minimum requirements.
Most of the cities in South Africa have well-managed landfills as well as recycling programs. Recycling activities are mostly private sector initiatives run by packaging manufacturers through buy-back facilities.

2. South African waste management perspective

Waste management in South Africa has in the past been uncoordinated and poorly funded. According to (Nahman & Godfrey, 2010) key issues include inadequate waste collection services for a large portion of the population, illegal dumping, unlicensed waste management activities (including unpermitted disposal facilities), a lack of airspace at

permitted landfills, insufficient waste minimization and recycling initiatives, a lack of waste information, lack of regulation and enforcement of legislation, and, indeed, limited waste-related legislation in the first place.
In response, the National Waste Management Strategy (NWMS) (Department of Environmental Affairs and Tourism [DEAT], 1999) emphasizes the need for integrated waste management, which implies coordination of functions within the waste management hierarchy. In particular, the diversion of waste from landfill through waste minimization and recycling is a national policy objective under the White Paper on Integrated Pollution and Waste Management (Department of Environmental Affairs and Tourism [DEAT], 2000), the NWMS and the Waste Act, which recognize the importance of moving waste management up the waste hierarchy (i.e. greater emphasis on waste avoidance, minimization and recycling to reduce impacts further downstream) (Nahman & Godfrey, 2010).
In addition, to deal with the issue of insufficient funding, the NWMS invokes the Polluter Pays Principle (PPP). In the context of solid waste management, the PPP implies that all waste generators, including households and companies, are responsible for paying the costs associated with the waste they generate. These include not only the direct costs associated with the safe collection, treatment and disposal of waste; but also the external costs (externalities) of waste generation and disposal, such as health and environmental damages (Department of Environmental Affairs and Tourism [DEAT], 1999).

3. Waste generation

- Commercial and Domestic General Waste

Municipal waste generated in recent years is increasing and mainly due to the increasing urbanization.
General waste – is waste that does not pose an immediate threat to man or the environment, that is, household and garden waste, builders' rubble and some dry industrial and business waste. It may, however, with decomposition and rain infiltration, produce leachate, which is unacceptable.
The mixed nature of general waste, the high proportion of recyclable material going to landfill, and the presence of small quantities of hazardous wastes are key challenges that need to be addressed.

- Mining and Industrial Hazardous Waste

The main sources of mining and industrial wastes are gold, platinum, coal, etc. and power industries, ore extraction, pulp and paper, petrochemical industries, etc.
According to (Adler, 2007), following the discovery of immense gold resources in South Africa in 1886, the mining industry played a central role in the country's economic, political, and social environment. Because minerals in South Africa are highly diversified, plentiful, and profitable, government has allowed the industry to be privileged, enabling it to maximize profits. But South Africa recently incorporated objectives of sustainability and social justice into its constitution. Not based on notions of sustainability, the early gold-economy was simply an extractive industry with little consideration given to possibly adverse long-term effects.
Hazardous waste – is waste containing or contaminated by poison, corrosive agents, flammable or explosive substances, chemical or any other substance which may pose detrimental or chronic impacts on human health and the environment.
Mining waste – is waste from any minerals, tailings, waste rock or slimes produced by, or resulting from, activities at a mine.

`The composition of mining waste varies according to the nature of the mining operation and many other factors, but where the same mineral is extracted from a similar style of metalliferous or industrial mineral deposit or coal, the waste usually has similar characteristics. There are many potential sources of industrial minerals from mining waste. Waste from one mine may be a byproduct or co-product in a mining operation elsewhere' (Scott et al., 2005).

Mining activities, from exploration to extraction and processing, have recently come under increasing public scrutiny in South Africa as competition for environmental resources has intensified and the post-Apartheid government's attitude has shifted towards improved environmental quality and health (Department of Minerals and Energy [DME], 1997).

'First, the nature of environmental and health risks from mining makes them difficult to quantify and even more difficult to evaluate in monetary terms. For example, in coal and other mining operations, surrounding downwind areas, which are not owned by mining firms, are often subject to dust particles emanating from the mines. In addition, acid run-offs can pose hazards to mine workers, to fish and wildlife, and to consumers when they persist in water and food` (Wiebelt, 1999). Most of these risks are not immediately apparent to either producers or consumers and the nature of these risks varies widely among types of mineral being extracted, on whether mining is onshore or offshore, and on the methods and technologies of extraction used. The major form of environmental externalities in South African mineral extraction is solid waste generation (Table 2).

The solid waste generated comprises of mostly potentially hazardous tailings and slags (Department of Environmental Affairs [DEA], 1992a). These make up the bulk of the mining's solid waste stream, which in turn represents nearly 90 percent of the total South African waste stream. Only 0.007 percent of mining waste takes the form of air emissions, and only 0.4 percent is discharged with waste water.

Although the quantity of waste discharged in waste water is small in comparison with the solid waste stream, the waste water stream is an important vehicle for hazardous mining waste. Table 2 shows that a small number of total waste streams in gold, platinum group metals, and antimony mining, and most of the waste in zinc refining have to be rated as hazardous with acid cyanide-containing goldmine effluents representing the largest hazardous waste stream in mining. However, it has to be kept in mind that environmental externalities in mining not only depend on the rates at which extraction takes place but also on the cumulative amounts of mineral ores already extracted.

It is estimated that backlog in mining waste includes some 12 billion tons of overburden and depleted processed ores, and about 30 thousand tons of semi-purified concentrates containing high concentration zinc, copper, cadmium or cobalt (Department of Environmental Affairs [DEA], 1992a). Thus, high environmental damages are incurred as a result of past and current mining activity.

Highly hazardous waste: contains significant concentrations of highly toxic constituents persistent in the environment and bio-accumulative;

Moderately hazardous waste: is highly explosive, flammable, corrosive or reactive, or is non-hazardous waste which are easily accessible, mobile or infective, or contains significant concentrations of constituents that are potentially highly toxic but only moderately mobile, persistent or bio-accumulative, or that are moderately toxic but are highly mobile, or persistent in the environment, or bio-accumulative;

Sector	Air Emissions	Waste Water	Solid/Liquid Waste	Total	Hazardous Waste[d]	Potentially Hazardous waste	Non-Hazardous Waste
Agriculture[b]	-	-	-	-	-	-	-
Coal mining	-	-	45,600	45,600	-	34,200	11,400
Gold mining	-	1,538	190,188	191.726	1,013	531	190.181
Other mining, of which	27	18	139,268	139,313	46	41	139,226
-Platinum group metals	27	27	45,137	45,182	18	28	45,136
-Phosphate	-	-	10.920	10,920	-	-	10,920
-Base metal	-	-	59,600	59,600	-	-	59,600
-Zinc	-	-	41	41	28	14	0
-Antimony	-	-	420	420	-	-	420
-Diamonds	-	-	23.000	23.000	-	-	23,000
-Asbestos	-	-	150	150	-	-	150
Total mining	**27**	**1.556**	**375,056**	**376,639**	**1.059**	**34,773**	**340.807**
Metallurgical and metals industries[c]	13	16	4,872	4,902	335	4,567	-
Non-metallurgical manufacturing industries	323	602	14,448	15,373	452	4,772	10,149
Services[c]	1,609	7	20.275	21,891	47	1,654	20,190
Total economy	**1,972**	**2,182**	**414.651**	**418,805**	**1,893**	**45.766**	**371,147**

[a]Excluding carbon dioxide emissions and sediments from waste water. - [b]Agriculture is not included in the survey [c]includes power generation. - [d]includes highly, moderately and low hazardous waste.

Table 2. Mining and industrial waste in South Africa, 1990/91 (thousand tons per annum)[a]

Low hazardous waste: is moderately explosive, flammable, corrosive or reactive, or contains significant concentrations of constituents that are potentially highly harmful to human health or the environment.
Potentially hazardous waste: often occurs in large quantities, and contains potentially harmful constituents in concentrations that in most instances would represent only a limited threat to human health or the environment.

4. South African environmental legislative framework

Hazardous wastes, in particular, require more stringent regulatory and technical controls due to their toxicity, persistence, mobility, flammability, etc. There is increasing public concern about the numerous problems and potentially dangerous situations associated with hazardous waste management in general and disposal practices in particular.
South Africa has introduced a range of legislative measures aimed at improving the quality of the environment. The effective regulation of hazardous wastes requires sufficient compliance and enforcement capacity on the part of Department of Environmental Affairs.
Waste in South Africa is currently governed by means of a number of pieces of legislation, including:

- The South African constitution Act 108 of 1996
- Hazardous Substance Act 5 of 1973
- Environmental Conservation Act 73 of 1989
- National Water Act 36 of 1998
- National Environmental Management Act 107 of 1998
- Minerals and Petroleum Resources Development Act 28 of 2002
- Air Quality Act 39 of 2004
- National Environmental Management: Waste Act 59 of 2008

The Environmental Management Policy for South Africa sets a number of objectives for integrated pollution control and waste management system.

The objectives include:

- Promoting cleaner production and establishing mechanisms to ensure continuous improvements in best practices in all areas of environmental management.
- Preventing or reducing and managing pollution of any part of the environment due to all forms of human activity, and in particular from radioactive, toxic and other hazardous substances.
- Setting targets to minimize waste generation and pollution at source and promoting a hierarchy of waste management practices, namely reduction of waste at source, reuse and recycling with safe disposal as the last resort.
- Regulating and monitoring waste production, enforce waste control measures, and coordinating administration of integrated pollution and waste management through a single government department.
- Setting up information systems on chemical hazards and toxic releases and ensuring the introduction of a system to track the transport of hazardous materials.

The South African waste management principles aim:

- To secure the conservation of nature and resources, waste generation must be minimized and avoided where possible (prevention principle).
- To secure a reduction in the impacts from waste on human health and environment, especially to reduce the hazardous substances in the waste through precautionary principle.
- To make sure that those who generate waste or contaminate the environment should pay the full costs of their actions through the principle of pollute pays and producer responsibility.

In relation to the mining waste, the strategic focus in terms of waste hierarchy is on ensuring the treatment and safe disposal of mining waste. However, opportunities for reuse of mining waste need to be fully exploited.

The overall goal with regard to regulating waste invariably is to minimize health and environmental impacts with the concurrent optimization of economic and social impacts on society.

5. Best practice technologies and possible approaches

Integrated Waste Management (IWM) maintains that waste management can be planned in advance because the nature, composition and quantities of waste generated can be predicted. Advanced planning, means that an orderly process of waste management can ensue. This includes:

- **Waste Prevention**: the prevention or avoidance of the production of certain wastes, sometimes by regulation. Waste prevention initiatives address the industrial sector, by promoting the use of cleaner technology as well as schools and private households in broader awareness campaigns. As prevention has the highest priority in waste management principles, South Africa should make efforts in order to aim at reducing the quantity of waste generated.
- **Waste Minimization:** the economic reduction of the volume of waste during production, by means of different processes, or uses, or 'clean' technology implementation; Waste minimization is the application of a systematic approach to reducing waste at source.
- **Resource Recovery**: recycling of wastes of one process as raw materials, or the recovery of energy through incineration or biodegradation. Recovery contributes to utilizing the resources embedded in waste and contributes to saving raw material.
- **Waste Treatment**: contributes towards the reduction in hazardous character of the waste, or its volume, to ease environmental or human health risks and impacts;
- **Waste Disposal**: is the preferred and mostly used option. This has traditionally been by the disposal of waste to landfill sites. Land filling is ranked the lowest in the hierarchy of waste due to the lack of utilization of the resources in the waste, yet, it remains to be the most common waste treatment method in South Africa, (See Fig. I).

Waste management hierarchical practices that remain a key principle of our waste management are in Table 3 below:

Waste Hierarchy	
Cleaner Production	Prevention
	Minimization
Recycling	Re-use
	Recovery
	Composting
Treatment	Physical
	Chemical
	Destruction
Disposal	Landfill

Table 3. Hierarchy of waste

"In terms of implementing the waste hierarchy for industrial and mining waste, waste avoidance and reduction is of particular importance due to the significant environmental impact of this waste, and the potential harmful consequences for human health. Where hazardous waste cannot be avoided, emphasis needs to be placed on regulation, not only in defining standards for treatment and disposal, but also in ensuring reuse and recycling takes place in a safe and responsible manner". (Department of Environmental Affairs [DEA], 2009).

6. Priority options: Waste minimization, recycling and recovery

In line with international norms, the National, Provincial and Local Authorities, as well as society and industry at large, are encouraged, in cases by regulation, to seek to implement measures and means by which waste generation and disposal rates can be economically reduced, including the adoption of cleaner technologies, separation and reclamation/recycling of wastes (see Fig. 1).

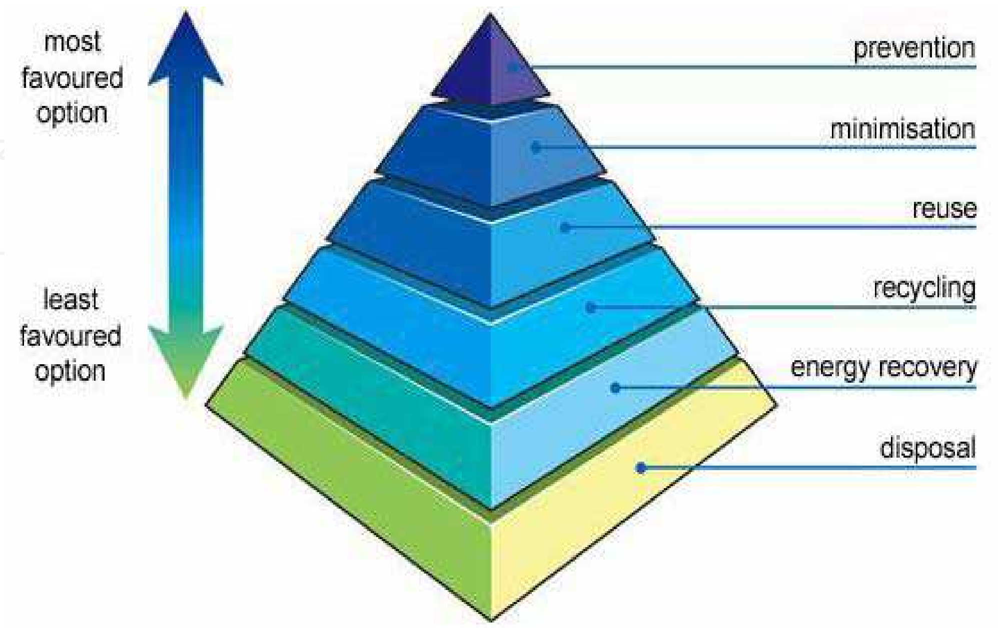

Fig. 1. The Waste Hierarchy

Waste minimizations involves a number of processes, mechanisms and stakeholders in the production, marketing, packaging, selling and consumption of goods that produce waste at all stages of the consumption cycle. By implication, it will require a conscious, comprehensive and intentional decision and effort by all stakeholders to ensure that waste and the secondary effects of poor waste management can be reduced through waste minimization to increase landfill site lifecycles and the environment. This may involve additional mechanisms and processes that include the following:

- Improving product and packaging designs to reduce resource consumption;
- Changing marketing and sales approaches to influence consumer perceptions and behaviour;
- "Extended Producer Responsibilities" (EPR) of producers of products, which may require producers to accept their used products back for recycling.
- Changing procurement policies and practices in large organizations that should encourage environmentally-aware production and manufacturing;
- Encouraging waste separation, streaming and diversion practices;
- Creating infrastructure to enable waste to be diverted from landfill sites;
- Developing infrastructure for processing waste for reuse/recycling;
- Developing markets for recycled materials and products;

7. Hazardous waste management

According to (Misra & Pandey, 2005), the management of hazardous wastes that has already been generated is one of the burning problems which require immediate attention. The principal objective of any hazardous waste management plan is to ensure safe, efficient and economical collection, transportation, treatment and disposal of wastes.

Steps towards effective management of hazardous wastes, and these are:

- Waste characteristics, including waste types, degree of hazards, chemical and physical stability, waste compatibilities, and the ability to segregate ignitable, reactive or incompatible wastes. To select suitable treatment and disposal techniques.
- Fate and transport characteristics of chemical constituents of wastes and their projected degradation products.
- The critical media of concern (such as air, surface water, ground water, soils/sediments, terrestrial and aquatic biota).
- Evaluation of potential release and exposure pathways of waste constituents and the potential for human and ecosystem exposures.
- Assessment of the environmental and health impacts of the wastes, if such waste reaches critical human and ecological receptors.
- Characterization of disposed sites, including site geology, topography, hydrogeology and meteorological conditions.
- Determination of extent of service area for proposed waste facility i.e. handling waste from local industry only or from regional and/or national generators.
- Suitability of proposed location for waste facility based on environmental, social and economic concerns including proximity to populations, ecological systems, water resources, etc.
- Best available technology (BAT) for handling the particular wastes. In addition, there should be contingency plans and emergency procedures in the design of waste management plans.
- Provision for effective long-term monitoring and surveillance programs including post-closure maintenance of facilities.

The capacity of a disposal facility is an exhaustible resource; however, the transportation of hazardous waste residue to disposal sites is a continuous process. In fact, the quantity of wastes arriving to a treatment/disposal facility may even increase over a period of time because of the industrial growth, unless waste minimization measures are implemented and enforced.

Rehabilitation of abandoned sites and re-entry therein and reuse also have to be done.

8. Treatment methods available

The purpose of treating waste is to convert it into non-hazardous substances or to stabilize or encapsulate the waste so that it will not migrate and present a hazard when released into the environment. Stabilization or encapsulation techniques are particularly necessary for inorganic wastes such as those containing toxic heavy metals.

Treatment methods can be generally classified as chemical, physical, thermal and/or biological.

Chemical methods - examples of chemical methods include neutralization, oxidation, reduction, precipitation and hydrolysis.

Physical methods - examples of physical methods include encapsulation, filtration, centrifuging and separation.

Thermal methods involve the application of heat to convert waste into less hazardous form. It also reduces the volume and allows opportunities for the recovery of energy from waste.

Biological methods involve the use of micro-organisms under optimised conditions to mineralise hazardous organic substances.

9. Landfill-disposal of hazardous waste

Disposal of the wastes is the final process and a key issue in overall hazardous waste management programme. The disposal facilities act as a permanent repository for the waste residues generated from the treatment facility. Even the most advanced treatment methods result in residues that are no longer amenable to cost-effective treatment.

The economics of waste disposal will determine, ultimately, the amounts and types of wastes that will be moved to distant disposal sites. The choice of disposal should be based on evaluation of economics and potential pollution risks.

The majority of domestic residential and commercial, business and industrial waste from urban areas is disposed to landfill sites. These landfill sites are generally operated by the local authority in whose area the site is located, or by private service providers. Although some of the industrial waste is handled by local authority services, and private service providers handle much of this stream. Most of the waste generated by industry (especially metallurgical) and agriculture are disposed of disposed of on the industrial or agricultural premises, with little information available on quantities, qualities or management thereof.

There are several environmental impacts from landfills. One impact is contribution to the greenhouse effect through the emission of methane gas. Leachate may also damage groundwater if there is no liner system. Other impacts include odours and general inconvenience for neighbours to landfill sites.

Waste management is emerging as a key sector for sustainable development in South Africa with opportunities for enhancing investments in carbon credits that target reduction of methane from landfills and moveable assets in relation to environmentally sound equipment required for effective waste management. It is true that the focus is towards two key areas for investments include capturing methane emissions from landfills for trading in carbon markets and financing both physical and moveable assets to enhance sustainable development. However, the challenges for cost-effectiveness, efficiency and sustainability in the sector prevail in relation to lack of sound knowledge to design and implement integrated programmes that incorporate environment, development and sustainability. Henceforth, financial resources according to (Karani & Jewasikiewitz, 2007), are imperative to waste management and sustainable development as the sector requires capital investments for necessary infrastructure.

10. Environmental and social impacts

According to (Adler, 2007) since negative externalities associated with mining were not internationalized under apartheid, the mining industry failed to adequately prepare for closure and to dispose of mine water and waste in a manner that is consistent with current international best practice.

Following the transition to democracy, government faces conflict caused by the legacy of weak regulation that has exaggerated problems associated with limited natural resources. In particular, cumulative harm to off-mine populations resulting from modified water tables, contaminated ground water sources, acidic mine drainage, and ground instability must be addressed before they lead to even more devastating socioeconomic, political, and environmental damage.

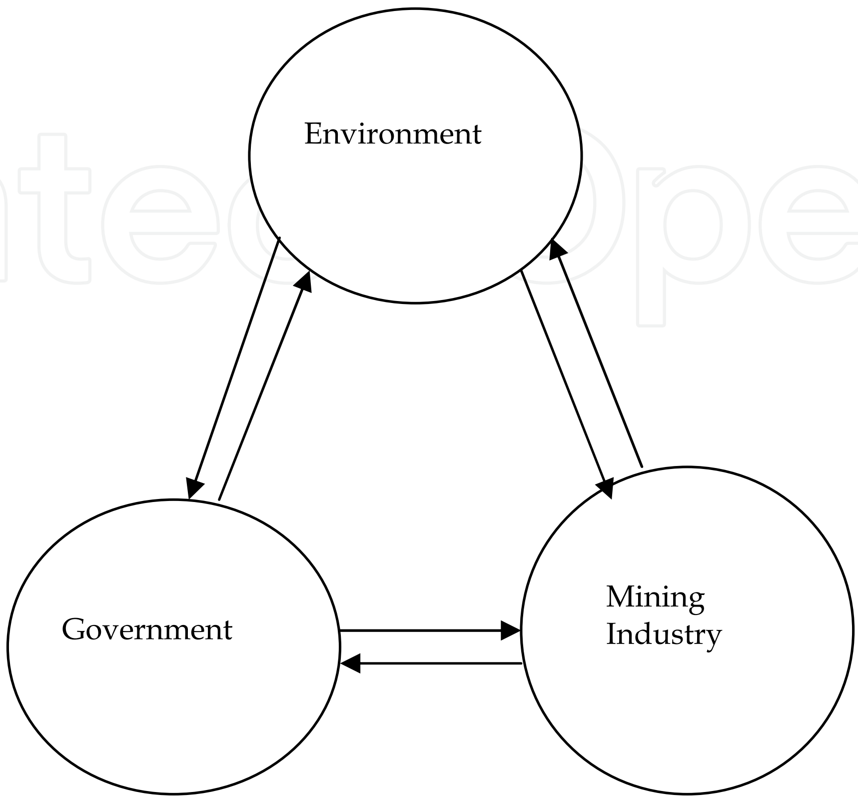

Fig. 2. Adapted Trialogue Model.

The trialogue model captures interactions among (1) government, (2) mining industry, and (3) environment. The environment includes society, economy, and the natural environment. Each sector places pressure on the others, as represented by the double arrows.

The outcome of these effects can be described in terms of governance Trialogue Model (Figure 2). It shows how regulation (or lack thereof) can result in conflict among industry, government, and environment (which includes society-at-large).

In the case of South Africa, new policies have been drafted by government to address these issues, but in most cases the regulation of mining-related activities is fragmented throughout multiple pieces of legislation, to be enforced by various agencies at the national, provincial, and municipal levels.

The impacts of non-sustainable waste management are difficult to quantify, however, potential consequences may be identified and include the following:

- Long term effects of pollutants entering the surface or groundwater resources, air and soil affecting the fitness for use, and availability of the resource for use. More specifically:
- Pollution of watercourses and groundwater by leaching of pollutants from waste inappropriately disposed of, or where waste management service provision is inadequate, particularly evident for dense urban informal settlements.
- Pollution of watercourses and groundwater by leaching of pollutants from waste residue deposits, particularly mine and power station waste dumps.
- Air pollution by dust releases from particularly mine residue deposits, but also general and hazardous waste sites (methane gas production) and HCRW incinerators.

- Nuisance from odours of waste degradation in landfill sites, waste disfiguring the environment especially plastic bags, and littering where waste service provision is limited.
- Reduced biological diversity in the areas of waste management operations, as a result of land disturbance or effects of emissions and discharges from the waste facilities.
- Increased waste management costs to provide safe and effective long-term disposal sites for increasing waste loads, including treatment of wastes to render them less environmentally available, and effective closure and rehabilitation of historically inadequate waste sites.
- Increased pressures through the negative societal impacts of inadequate service provision fostering illegal waste dumping, littering and abuse of open spaces.
- Increased health and environmental risks associated with inadequate waste collection and disposal services, and informal salvaging on landfill sites.
- Poverty encourages salvaging on waste sites for recyclables, refuge materials, fuel and food.
- Environmental risks as many waste sites which do not meet the Minimum Requirements stipulated by DWAF, requiring upgrading to the specifications, or closure and rehabilitation.

Although hazardous waste is produced by practically all areas of society, some of the worst waste produced, with a legacy of the poorest controls, comes from the mines and industries. Some of these contaminants are discharged into the aquatic environment.

The consequences and impacts of waste management inherently link to other indicators of environmental health and sustainability, particularly:

- Water resource, the focus being on water quality deterioration and pollution;
- Biodiversity;
- Social environment, the focus being on human health;
- Air quality, the focus being on visual and odour nuisance; and
- Land, the focus being on provision of suitable locations for landfills and waste services.

11. Economic impacts

According to (Wiebelt, 1999), while in many developed countries mining has been relegated to the status of an ugly old industry of little importance to the national wealth, the highly mineralized nature of many parts of South Africa has led to the creation of a mining industry which is quite important to the country's economy.

If the value of processed mineral products such as refined base metals, ferroalloys, iron and steel, and refinery products produced from coal were included, about 60 percent of South African export revenue would have come from mineral-based products.

The Department of Environmental Affairs proposed `eco-taxes', whereby polluters are charged equal to their hazardous waste treatment costs allow the realization of any technologically possible environmental objective at minimum social costs. The analysis is based on a study by the Department of Environment Affairs on Hazardous Waste in South Africa which among others estimates hazardous and non-hazardous waste streams for different sectors (Department of Environmental Affairs [DEA], 1992a) and assesses the economic impact of alternative policies towards hazardous waste management (Department of Environmental Affairs [DEA], 1992b).

The economic impacts of hazardous waste may be clustered along the following three categories:

- The environmental tax on hazardous mining waste will lead to an adjustment of factor demand and final demand and, therefore, to an environmentally more sound use of natural resources.
- Closely connected with the environmental impacts are the economic impacts of the environmental tax. Higher costs for waste management lead to changes in macroeconomic aggregates which have to be included in the analysis. Income and substitution effects will change the international competitiveness of individual sectors as well as the sectoral structure of the economy.
- The taxation of hazardous mining waste will yield higher tax revenues, higher tax revenues.
- Economic instruments such as environmental taxes and subsidies should provide incentives for waste generators and service providers to reduce waste generation and to seek alternatives to final disposal to landfill such as re-use, recycling and recovery. There are opportunities that are associated with the implementation of economic instruments and they include:
  - Potential to reduce the need for landfill airspace and prolong the lifespan of landfill sites;
  - Their potential to stabilise prices of recyclables and thus stimulate and stabilise viable and sustainable markets for recyclables;
  - The socio-economic benefits associated with recycling such as local economic development and the creation of job opportunities in the recycling market;
  - Improved environmental awareness; and
  - The potential to encourage private investment.

12. Conclusion

South Africa has developed waste regulations; and awareness has been created for the management of hazardous wastes; however, effective practice for safe management still needs to be enforced.

To effectively manage waste, public-private partnership should be encouraged to jointly address waste management problems.

The partnership mechanisms would address the following:

- Significantly reducing load of hazardous waste to landfills.
- Finding alternative uses for industrial waste generated in significant quantities with a high potential for environmental pollution.
- Addressing the problem of reluctance from industries to disclose their hazardous waste streams and volumes.

In trying to deal with waste management challenges in South Africa, it is important to rigorously

- Consider both recycling and waste minimization
- Consider extended producer responsibility as a means to emphasize waste minimization
- Explore opportunities for energy recovery
- Ban some waste streams from landfill sites.

An obligation should be made to monitor landfills during their operation and up to 30 years after their closure. The monitoring must include measurement of landfill runoff, emissions of landfill gas, the level of water table and ground water quality under and near the landfill.

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This book reports mostly on institutional arrangements under policy and legal issues, composting and vermicomposting of solid waste under processing aspects, electrical and electronic waste under industrial waste category, application of GIS and LCA in waste management, and there are also several research papers relating to GHG emission from dumpsites.